Effects of Different Grinding Particle Size Combinations of Starter and Finisher Diets on Broiler Growth Performance (Postprint)

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Abstract

This experiment aimed to investigate the effects of different grinding particle sizes on feed processing quality and the effects of diets with different grinding particle sizes on growth performance of broiler chickens at different growth stages. A total of 864 one-day-old white-feathered Arbor Acres (AA) broiler chickens were selected and randomly divided into 6 groups with 8 replicates per group and 18 birds per replicate, for a 42-day feeding trial divided into two phases: starter phase (1-21 days of age) and grower phase (22-42 days of age). For the starter phase, 3 groups were established: the 1.5 mm group had 24 replicates, the 2.0 mm group had 16 replicates, and the 2.5 mm group had 8 replicates; for the grower phase, 6 groups were established: the starter-phase 1.5 mm group was evenly divided into 3 groups, the 2.0 mm group was evenly divided into 2 groups, and the 2.5 mm group remained unchanged, with 8 replicates per group. The results showed: 1) The geometric mean particle size of feed increased with increasing screen aperture size, with the 2.5 mm group being significantly greater than the 1.5 and 2.0 mm groups ($P<0.05$); pellet durability index (PDI), pellet hardness, and starch gelatinization degree decreased with increasing screen aperture size, with the 1.5 mm group having significantly greater PDI and pellet hardness than the 2.0 and 2.5 mm groups ($P<0.05$); as screen aperture size increased, there were no significant differences in the in vitro crude protein digestibility of feed among groups ($P>0.05$). 2) During days 1-21, the 2.0 mm group had the highest average body weight at 21 days, average daily feed intake, and average daily gain. During days 22-42, the group with 2.0 mm in the starter phase and 2.5 mm in the grower phase had the highest average body weight at 42 days and average daily gain, and the lowest feed conversion ratio; the group with 1.5 mm in the starter phase and 2.5 mm in the grower phase had the highest average daily feed intake. Based on these comprehensive results, the group with 2.0 mm in the starter phase and 2.5 mm in the grower phase exhibited the best growth performance. Therefore, grinding starter diets

with a 2.0 mm screen aperture and grower diets with a 2.5 mm screen aperture yielded optimal growth performance in broiler chickens.

Full Text

Effects of Different Diet Particle Size Combinations on Growth Performance of Broilers in Early and Later Periods

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Abstract

This study investigated the effects of different grinding particle sizes on feed processing quality and broiler growth performance at different growth stages. A total of 864 one-day-old white-feathered Arbor Acres (AA) broilers were randomly allocated to 6 groups with 8 replicates per group and 18 birds per replicate. The 42-day feeding trial consisted of two phases: early period (1–21 days) and later period (22–42 days). Diets for each phase were ground using screen mesh sizes of 1.5, 2.0, and 2.5 mm, with 4 replicates per mesh size. In the early period, three groups were established: 24 replicates for the 1.5 mm group, 16 replicates for the 2.0 mm group, and 8 replicates for the 2.5 mm group. In the later period, six groups were formed by subdividing the early-period groups: the 1.5 mm group was divided into three equal subgroups, the 2.0 mm group into two equal subgroups, and the 2.5 mm group remained unchanged, with 8 replicates per group. The results showed: (1) Geometric mean particle size increased with screen mesh size, with the 2.5 mm group significantly larger than the 1.5 and 2.0 mm groups ($P<0.05$). Particle durability index (PDI), particle hardness, and starch gelatinization degree decreased as screen mesh size increased, with the 1.5 mm group showing significantly greater PDI and hardness than the 2.0 and 2.5 mm groups ($P<0.05$). Crude protein digestibility in vitro did not differ significantly among groups ($P>0.05$). (2) During 1–21 days, the 2.0 mm group achieved the highest 21-day average body weight, average daily feed intake, and average daily gain. During 22–42 days, the combination of 2.0 mm in the early period and 2.5 mm in the later period yielded the highest 42-day average body weight and average daily gain, along with the lowest feed-to-gain ratio. Based on these results, the optimal grinding protocol was 2.0 mm screen mesh for the early period and 2.5 mm for the later period.

Keywords: particle size; broilers; feed processing quality; growth performance

Introduction

Particle size is a critical parameter in feed processing that should be determined based on feed type, animal species, growth stage, and processing requirements [1]. Appropriate particle size can improve pellet quality, feed conversion efficiency, and animal performance while reducing waste and enhancing production efficiency [2,3]. Nir et al. [4] reported that medium particle size (700–900 m) of grains in broiler diets optimized growth performance. Ribero et al. [5] found that increasing particle size from 337 m to 868 m in 21–42-day-old broiler diets increased body weight, though further increases to 936 m reduced feed intake and daily gain. Other studies have shown that increasing particle size from 900 m to 1,470–1,750 m significantly reduced daily gain and feed conversion efficiency [6]. While excessive particle size impairs broiler performance, most research has focused on using a single particle size throughout the entire growth period, with limited studies investigating different particle size combinations for different growth stages. This experiment examined the effects of varying dietary particle sizes across different growth stages to determine optimal grinding parameters for feed manufacturers.

Materials and Methods

1.1 Experimental Animals and Design

The trial was conducted at the Nankou Experimental Base of the Chinese Academy of Agricultural Sciences using a single-factor design. A total of 864 one-day-old white-feathered Arbor Acres (AA) broilers with initial body weight of (48.00$\pm$0.05) g were randomly allocated to 6 groups (8 replicates per group, 18 birds per replicate) following a 42-day feeding protocol divided into early (1–21 days) and later (22–42 days) periods. Diets for both periods were ground using screen mesh sizes of 1.5, 2.0, and 2.5 mm, with 4 replicates per mesh size. In the early period, three groups were established: 24 replicates for the 1.5 mm group, 16 replicates for the 2.0 mm group, and 8 replicates for the 2.5 mm group. In the later period, six groups were created by subdividing the early-period groups: the 1.5 mm group was divided into three equal subgroups, the 2.0 mm group into two equal subgroups, and the 2.5 mm group remained unchanged, with 8 replicates per group. Mash feed was provided during the early period, while 3.0 mm pellets were fed during the later period. Pellet processing conditions included a 3.0 mm ring die, length-to-diameter ratio of 10:1, and conditioning temperature of 80 °C. Birds were housed in single-tier cages.

1.2 Experimental Diets

Diet composition and nutrient levels are presented in Table 1 . The premix provided the following per kg of diet: for 1–21 days: VA 10,000 IU, VD_3 1,000 IU, VE 20 IU, VK_3 0.5 mg, VB_1 2.0 mg, VB_2 8.0 mg, pantothenic acid 10.0 mg, niacin 35.0 mg, VB_6 3.5 mg, biotin 0.05 mg, folic acid 0.55 mg, VB_{12} 0.01 mg, choline 1,300 mg, Fe (as ferrous sulfate) 100 mg, Cu (as copper sulfate) 8.0 mg, Zn (as zinc sulfate) 100 mg, Mn (as manganese sulfate) 120 mg, I (as potassium iodide) 0.7 mg, Se (as sodium selenite) 0.3 mg, flavomycin 6 mg, salinomycin 70 mg. For 22-42 days: VA 8,000 IU, VD_3 750 IU, VE 15 IU, VK_3 0.5 mg, VB_1 2.0 mg, VB_2 5.0 mg, pantothenic acid 10.0 mg, niacin 30.0 mg, VB_6 3.5 mg, biotin 0.05 mg, folic acid 0.55 mg, VB_{12} 0.01 mg, choline 1,000 mg, Fe (as ferrous sulfate) 80 mg, Cu (as copper sulfate) 8.0 mg, Zn (as zinc sulfate) 80 mg, Mn (as manganese sulfate) 100 mg, I (as potassium iodide) 0.7 mg, Se (as sodium selenite) 0.3 mg, flavomycin 4 mg, salinomycin 50 mg. Crude protein was measured, while other nutrient levels were calculated values.

1.3 Management

Management followed the AA broiler manual. Lighting and temperature were controlled, ventilation maintained, and houses regularly disinfected, cleaned, and de-manured. Vaccination followed the prescribed program. Bird condition was monitored, mortality recorded, and feed consumption measured. Birds had ad libitum access to feed and water.

1.4 Measurements

1.4.1 Particle Size: Three samples were collected per group at each sampling point. Geometric mean particle size was determined using the 14-sieve method from GB/T 6971-2007 "Test Methods for Feed Mills" [7].

1.4.2 Pellet Hardness: Measured according to the method for pellet hardness determination in "Feed Inspection and Testing" [8].

1.4.3 Particle Durability Index (PDI): Five hundred grams of sieved pellets (fines removed) were tumbled for 10 min in a durability tester, then sieved and reweighed. PDI was calculated as: PDI (%) = 100 × (weight after tumbling / weight before tumbling) [9].

1.4.4 Starch Gelatinization Degree: Determined using a simplified enzymatic method [10].

1.4.5 Crude Protein Digestibility in Vitro: Crude protein content was measured by the Kjeldahl method [11], and in vitro digestibility was determined according to Wang et al. [12].

1.4.6 Growth Performance: Feed was withdrawn at 20 and 41 days for 24 h with free access to water. Birds were weighed individually at 21 and 42 days to calculate average body weight per replicate. Daily feed intake was recorded, and feed remaining was weighed when mortality occurred to calculate total feed consumption per phase. Average daily feed intake (ADFI, g) = total feed consumption / (number of birds × days); Average daily gain (ADG, g) = total weight gain / (number of birds × days); Feed-to-gain ratio (F/G) = total feed consumption / total weight gain.

1.5 Data Processing

Data are expressed as "mean ± standard deviation." One-way ANOVA was performed using SPSS software, with Duncan' s multiple comparison applied when significant differences were detected ($P<0.05$). Differences among screen mesh sizes were tested for feed processing quality, while group differences were analyzed separately for early and later periods for growth performance.

Results

2.1 Effects of Particle Size on Feed Processing Quality

Effects of particle size on geometric mean particle size, crude protein digestibility in vitro, pellet hardness, PDI, and starch gelatinization degree are shown in Table 2 . Geometric mean particle size increased with screen mesh size, with the 2.5 mm group significantly larger than the 1.5 and 2.0 mm groups ($P<0.05$), while the 1.5 mm group had the smallest particle size. Crude protein digestibility in vitro did not differ significantly among groups as screen mesh size increased ($P>0.05$). PDI decreased with increasing screen mesh size, with the 1.5 mm group significantly higher than the 2.0 and 2.5 mm groups ($P<0.05$), indicating that smaller particle sizes facilitate pellet formation and reduce fines. Pellet hardness also decreased as screen mesh size increased, with the 1.5 mm group significantly harder than the 2.0 and 2.5 mm groups ($P<0.05$). Starch gelatinization degree decreased with increasing screen mesh size; for 1–21 day diets, the 1.5 and 2.0 mm groups were significantly higher than the 2.5 mm group ($P<0.05$), while no significant differences were observed among 22–42 day diets ($P>0.05$), suggesting that smaller particle sizes favor starch gelatinization.

2.2 Effects of Particle Size on Broiler Growth Performance

Effects of different particle sizes on early-period growth performance are presented in Table 3 . The 2.0 mm group had significantly higher 21-day average body weight than the 2.5 and 1.5 mm groups ($P<0.05$), and the 2.5 mm group was significantly higher than the 1.5 mm group ($P<0.05$). Average daily feed intake was significantly higher in the 2.0 mm group than in the 2.5 mm group ($P<0.05$). The 2.0 mm group achieved the highest average daily gain, followed by the 2.5 mm group and then the 1.5 mm group, though differences were not significant ($P>0.05$). The 2.5 mm group had a significantly lower feed-to-gain ratio than the 2.0 and 1.5 mm groups ($P<0.05$).

Effects on later-period growth performance are shown in Table 4 . No significant differences were observed among groups for any performance indicators ($P>0.05$). However, trends indicated that the combination of 2.0 mm in the early period and 2.5 mm in the later period yielded the highest 42-day average body weight and average daily gain with the lowest feed-to-gain ratio. The combination of 1.5 mm in the early period and 2.5 mm in the later period resulted in the highest average daily feed intake. Overall, the 2.0 mm early period + 2.5

mm later period combination provided the best growth performance and feed conversion efficiency.

Effects on whole-period growth performance are presented in Table 5 . No significant differences were detected among groups (P>0.05). Trends showed that the 1.5 mm early + 2.5 mm later combination had the highest average daily feed intake, while the 2.0 mm early + 2.5 mm later combination achieved the highest average daily gain. The lowest feed-to-gain ratios were observed in the 1.5 mm early + 1.5 mm later, 2.0 mm early + 2.5 mm later, and 2.5 mm early + 2.5 mm later groups. Based on these results, the 2.0 mm early + 2.5 mm later combination provided optimal growth performance, suggesting that broiler diets should be ground with a 2.0 mm screen in the early period and a 2.5 mm screen in the later period.

Discussion

3.1 Effects of Particle Size on Feed Processing Quality

The particle size distribution of individual components significantly influences pellet quality, with raw material particle size accounting for 15-20% of pelleting effects. Wang et al. [12] used a 9FQ-25 hammer mill with five screen sizes (4.0, 2.5, 1.5, 1.0, and 0.6 mm) to grind corn and soybean meal, finding that geometric mean particle size decreased with smaller screen apertures. Our study using 1.5, 2.0, and 2.5 mm screens showed that geometric mean particle size increased with screen aperture, consistent with Wang et al. [12]. Li [13] reported that PDI values for corn ground at 400, 600, 800, and 1,000 m were 86.4%, 82.4%, 79.4%, and 78.8%, respectively, demonstrating that PDI increases as particle size decreases. Xie et al. [14] found that pellet fines rates and hardness at particle sizes of 356, 397, and 561 m were 3.46%, 6.25%, 9.73% and 4.52, 3.81, 2.76 kg, respectively, similar to Li [13], indicating that pellet hardness also increases with decreasing particle size. Our results showing decreased pellet hardness and PDI with increasing particle size align with these findings, likely because coarse grinding creates surface cracks that reduce durability and hardness. Research has shown that decreasing particle size from 600 m to below 100 m increased starch gelatinization from 44% to 56%, as smaller particles provide greater surface area for steam contact during conditioning, facilitating heat and moisture transfer and improving gelatinization and pellet formation [15,16]. Wang et al. [17] reported that in vitro protein digestibility of various feed ingredients increased with decreasing particle size. Cheng et al. [18] found that protein digestibility in carp diets increased with smaller particle sizes before and after conditioning and pelleting. However, our study showed no significant change in crude protein digestibility with particle size, possibly because the narrow range of screen sizes (1.5-2.5 mm) produced insufficient variation in particle size to affect enzyme contact area.

3.2 Effects of Particle Size on Broiler Growth Performance

Particle size directly affects broiler growth performance. Smaller particles increase feed surface area and nutrient-enzyme contact, improving digestion efficiency. However, excessive grinding increases energy costs, reduces palatability, and may cause gastrointestinal issues including ulcers [19]. Rennce et al. [20] reported that reducing corn particle size from 1,024 m to 910 m improved feed conversion in broilers fed pelleted diets. Our study found that grinding 1–21 day diets with a 2.0 mm screen (geometric mean particle size 367.48 m) maximized 21-day body weight, feed intake, and daily gain. This may be because large particle sizes impair young bird performance by slowing gizzard passage; chicks' underdeveloped gizzards cannot effectively break down large particles, and reduced enzyme contact lowers digestibility. Conversely, excessively fine particles reduce palatability and feed intake, impairing growth. Research indicates that particle size can increase with broiler age [6]. Ribero et al. [5] showed that increasing particle size from 337 m to 868 m in 21–42 day diets increased body weight. Our finding that a 2.5 mm screen (geometric mean particle size 427.17 m) optimized later-period performance aligns with Ribero et al. [5], possibly because larger particles promote gastrointestinal development [21], allowing longer retention in the upper digestive tract, increased gut motility, and enhanced enzyme activity.

Conclusion

1. As screen mesh size increased, feed particle size increased while pellet hardness, PDI, and starch gelatinization degree decreased; crude protein digestibility in vitro was not significantly affected.

2. Considering both feed processing quality and broiler growth performance, diets for 1–21 day-old broilers should be ground with a 2.0 mm screen (geometric mean particle size 367.48 m), and diets for 22–42 day-old broilers with a 2.5 mm screen (geometric mean particle size 427.17 m).

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Note: Figure translations are in progress. See original paper for figures.